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Effect of sowing temperature on growth & yield of Indian Mustard (*Brassica juncea* L.)

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Abstract
A field experiment was conducted during the *Rabi* season of 2015-16 to access the "Effect of sowing temperature on growth and yield of Indian Mustard (*Brassica juncea* L.)" in silty loam soil at Agro-meteorological Research Farm, N.D. University of Agriculture & Technology, Kumarganj, Faizabad. The experiment was conducted with nine treatment combinations consisted of three dates of sowing *viz.* D_1 (7th November), D_2 (17th November) and D_3 (27th November) and three cultivars *viz.* V_1 (Varuna), V_2 (NDR-8501) and V_3 (NDR-4). Results revealed that 7th November sown mustard crop produced significantly higher growth and yield due to fulfilment of optimum thermal requirement and solar light requirement for various processes of plant. Among the different cultivars of mustard, NDR-8501 was found more conducive for growth, development and thermal use efficiency as compared to Varuna and NDR-4. Higher seed yield (19.14q/ha) was recorded under 7th November sowing date having average temperature 24.4 ^{0}C as compared to 17th November (21.5 ^{0}C) sown mustard crop and 27th November (18.7 ^{0}C). Thermal unit (1796 ^{0}C days) and Photo-thermal index (84.06) from sowing to maturity produced the high yield of Indian mustard.

Keywords: sowing temperature, Indian mustard, sown mustard crop

Introduction
Rapeseed-mustard is the third important oilseed crop in the world after soybean (*Glycine max* L.) and palm (*Elaeis guineensis* Jacq.) oil. It is grown in subtropical and tropical countries in the world comprise eight cultivated crops of tribe Brassiceae within the family Cruciferae (Brassicaceae). Cool temperature, dry weather with good amount of bright sunshine increases the oil yield. Mustard needs high temperature for vegetative growth (20 ºC-32 ºC) and cool temperature with clear sky during reproductive growth and maturity. Rapeseed - mustard follows C_3 pathway for carbon assimilation. Therefore, it has efficient photosynthetic response at 15 ºC to 20 ^{0}C temperature. Rapeseed–mustard crops are grown in diverse agro-climatic conditions ranging from north-eastern/ north-western hills to down south under irrigated/rainfed, timely/ late-sown, saline soils and mixed cropping. Production potentiality of Indian mustard can be fully exploited under these conditions with suitable agronomic practices and varieties.

Among the different agronomic practices, optimum sowing time is very important for mustard production (Mondal and Islam, 1993; Mondal *et al.*, 1999) [2, 3]. Research findings have also shown that sowing date is one of the critical components affecting mustard crop productivity. It is one of the most important agronomic factor and non-monetary input which pave the way for better-use of time and play an important role to fully exploit the genetic potentiality of a variety as it provides optimum growth conditions such as temperature, light, humidity and rainfall. Sowing period information is needed for various other purposes like adjusting crop rotations; cropping patterns, crop growth simulations and climate change impact studies. The temperature and solar radiation play an important role in partitioning of biomass between various organs of plant which is related to, and often governed by phenological phase of the plant and the way in which a crop develops can affect the yield and yield attributes.

The growth phase of the crop should synchronize with optimum environmental conditions for better expression of growth and yield. It is a fact that specified genotypes does not exhibit the same phenotypic characteristics in all environmental conditions. Bora (1997) has reported that the yield potential of different mustard varieties may differ under different agro-climatic conditions because of their inherent capacity. The different genotype growth response varies to different environment and their relative ranking usually differ and ultimately decides the selection of genotypes for a particular or different sowing dates for stabilized higher yields (Eberhort and Russel, 1966 and Perkins and Jinks, 1968) [1, 4]. The mustard genotypes differ in their yielding ability, this calls for a need to generate more information on the response of mustard genotypes to the dates of sowing for greater yields in a given agro-climatic condition. Different cultivars respond variability under different weather conditions. The research work on above aspect is meager under agro-climatic condition of eastern U.P. Hence present investigation was undertaken.

Materials and Methods

A field experiment was conducted in silty loam soil at Agro-meteorological Research Farm, N.D. University of Agriculture & Technology, Kumarganj, Faizabad. The experiment was conducted in RBD design with nine treatment combinations consisted of three dates of sowing *viz*. D_1 (7^{th} November), D_2 (17^{th} November) and D_3 (27^{th} November) and three cultivars *viz.* V_1 (Varuna), V_2 (NDR-8501) and V_3 (NDR-4). The experimental site was located at 26˚47′ N latitude and 82˚12′ E longitude and at an attitude of about 113 meter above the mean sea level.

Photo thermal index measured at different sowing dates were calculated as per following formula**:**

Photo thermal index = GDD/ Growing days

Accumulated growing degree days (GDD) at different phenological stages were calculated by using following formula:

$$\textbf{Accumulated GDD} = \sum_{i=1}^{n} \text{heat unit (HU)}$$

Where, 1, 2, 3, ……………... n is number of days and

$$\textbf{Heat unit} = \frac{T_{Max.\ Temp.} + T_{Min.\ Temp.}}{2} - \text{Base temp } (T_b).$$

Base temperature for mustard (*Rabi*) crop 5.0°C.

Heat use efficiency (HUE) was calculated from heat unit obtained above as following –

$$\textbf{HUE} = \frac{\text{Total dry matter (g/m}^2\text{)}}{\text{Heat unit (}^0\text{days)}}$$

Results and Discussions

Data presented in table no. 1 reveal that number of siliquae/ plants was significantly affected due to different sowing temperature. Maximum number of siliquae/ plant (278.58) were recorded when crop was sown on 7^{th} November which was significantly superior over 17th November and 27th November sowing temperatures. The minimum number of siliquae/ plants was recorded when sowing was done on 27^{th} November. Length of siliquae (cm) showed that different sowing temperatures is significant to the length of siliquae(cm). Maximum length of siliquae (7.25cm) was recorded when crop was sown on 7^{th} November which was significantly superior over 17^{th} November and 27^{th} November sowing date/temperature. The minimum length of siliquae (6.45cm) was recorded when sowing was done on 27^{th} November. Number of seeds/siliquae showed that different sowing temperatures were significant to the number of seeds/ siliquae (Charak *et. al.*, 2006; Jha *et. al.*, 2012) [5, 6]. Maximum number of seeds/siliquae (13.81cm) was recorded when crop was sown on 7^{th} sowing temperature which was significantly superior over 17^{th} November and 27^{th} November sowing date/temperature. The lowest number of seeds/siliquae was recorded when sowing was done on 27^{th} November. Test weight was affected significantly due to sowing temperatures. Higher test weight (4.30g) was observed when it was sown on 7^{th} November. Significantly higher numbers of siliquae/plant (292), length of siliqua (7.64cm), numbers of seeds/siliqua (14.21) and test weight (4.35g) were recorded with NDR-8501 cultivar which was at par with Varuna (269.41) while significant over NDR-4.

Significantly higher seed yield (1913.50 Kg/ ha) was obtained when crop was sown on 7^{th} November which is significant superior over crop sown on 17^{th} November and 27^{th} November. Straw yield (kg/ ha) was significantly affected by sowing temperatures (Table 2). Higher straw yield (6884.58 Kg/ ha) was obtained when crop was sown on 7^{th} November which is significant superior over crop sown on 17^{th} November and 27^{th} November. Biological yield (kg/ ha) was significantly affected by sowing temperature. Significantly higher biological yield (8798.08 Kg/ ha) was obtained when crop was sown on 7^{th} November which is significantly superior over 17^{th} November and 27^{th} November sowing date/temperatures. Harvest index (%) was affected by sowing date/ temperatures/ temperatures. Significantly Maximum harvest index (21.58) was obtained when crop was sown on 7^{th} November which is significantly superior over crop sown on 17^{th} November and 27^{th} November. Seed yield (kg/ha) was significantly affected by different varieties. Maximum Seed yield (1912.25 Kg/ha) and Straw yield (6965.91 Kg/ha) was recorded with NDR-8501 cultivar followed by Varuna (1861.24 Kg/ha).

Higher thermal unit from emergence to pod maturity was recorded for 7^{th} November. However from sowing to emergence, higher thermal unit was recorded for 27^{th} November (Table-3). The maximum heat unit/thermal unit (GDD) requirement from sowing to maturity (1796.5ºC days) were recorded for 7^{th} November followed by (1784.5ºC days) for 17^{th} November while minimum accumulated growing degree day from sowing to maturity (1721.75ºC days) was obtained for crop sown on 27^{th} November. The maximum Photo thermal Index from sowing to maturity (89.17) was recorded for 7^{th} November sown date while minimum Photo thermal Index (73.59) from sowing to maturity was observed for 27^{th} November (Table 4). The thermal use efficiency (g/m^2/days) requirement from sowing to maturity (0.47) was recorded for 7^{th} November followed by (0.45) for 17^{th} November while minimum thermal use efficiency from sowing to maturity (0.41) was observed for 27^{th} November sown crop as presented in Table-5 (Keerthi *et. al.*, 2016) [7]. Maximum thermal use efficiency (0.48) and Photo thermal Index of (84.06) requirement from sowing to maturity were obtained in NDR-8501 cultivar while minimum thermal use efficiency was obtained in Varuna (0.44) from sowing to maturity of Indian mustard.

Table 1: Yield attributes of Indian mustard as affected by sowing temperatures and cultivars.

Treatments	No. of Siliquae/plant	Length of siliqua (cm)	No. of seeds/siliqua	Test weight (g)
Date of Sowing/ Sowing temperature (3)				
7thNov (24.5^{0}C)	278.58	7.25	13.81	4.30
17thNov (21.5^{0}C)	275.50	7.09	12.80	4.21
27thNov (18.7^{0}C)	253.66	6.45	12.03	4.00
SEm±	7.09	0.20	0.36	0.08
CD at 5%	20.69	0.60	1.07	0.23
Cultivars (3)				
Varuna	269.41	7.00	13.03	4.21
NDR-8501	292.00	7.64	14.21	4.35
NDR-4	246.33	6.16	11.40	3.95
SEm±	7.09	0.20	0.36	0.08
CD at 5%	20.69	0.60	1.07	0.23

Table 2: Yield of Indian mustard as affected by sowing temperatures and cultivars

Treatments	Seed Yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)
Date of Sowing/ Sowing temperature (3)			
7th Nov/24.5^{0}C	1913.50	6884.58	21.74
17th Nov/21.5^{0}C	1823.91	6624.91	21.58
27th Nov/18.7^{0}C	1676.33	6362.25	20.85
SEm±	47.87	126.98	0.11
CD at 5%	139.74	370.67	0.33
Cultivars (3)			
Varuna	1861.24	6504.08	21.24
NDR-8501	1912.25	6965.91	22.08
NDR-4	1640.25	6401.75	21.90
SEm±	47.387	122.96	0.11
CD at 5%	139.74	358.93	0.33

Table 3: Accumulated thermal unit at different phenophases (˚C days) of Indian mustard as affected by sowing temperatures and cultivars

Treatments	Phenophases					
	Emergence	Four Leaf Stage	Flower Initiation	Siliquae Initiation	Pod Develop -ment	Maturity
Date of Sowing/ Sowing temperature (3)						
7thNov (24.5ºC)	91.50	279.75	455.00	689.25	1078.20	1796.5
17thNov (21.5ºC)	94.25	330.50	532.75	741.55	1086.25	1784.5
27thNov (18.7^{0}C)	96.00	351.50	658.75	898.50	1145.75	1726.7
Cultivars (3)						
Varuna	94.48	345.75	582.24	816.45	1148.33	1846.0
NDR-8501	93.60	320.50	548.83	776.55	1103.66	1716.5
NDR-4	92.96	295.25	491.85	705.20	1096.03	1608.9

Table 4: Photo thermal Index at different phenophases of Indian mustard as affected by different growing environments and cultivars.

Treatments	Photo thermal Index						
	Sowing To Emergence	Emergence To Four Leaf Stage	Four Leaf Stage to Flower Initiation	Flower ignition To Siliquae Initiation	Siliquae Initiation to Pod Development	Pod Development To Maturity	Sowing to Maturity
Date of Sowing/ Sowing temperature (3)							
7thNov (24.5^{0}C)	18.30	11.76	16.17	10.42	16.20	16.32	89.17
17thNov (21.5^{0}C)	15.70	13.12	9.65	9.49	13.25	18.37	79.58
27thNov (18.7^{0}C)	13.71	12.77	8.34	9.76	9.15	19.86	73.59
Cultivars (3)							
Varuna	15.74	13.95	10.74	10.18	12.29	19.38	82.28
NDR-8501	15.60	12.60	9.13	11.38	15.57	19.78	84.06
NDR- 4	15.49	11.89	7.02	13.33	14.47	18.31	80.51

Table 5: Thermal use efficiency (g/m²/ºdays) of Indian mustard as affected by sowing temperatures and cultivars.

Treatments	Thermal use efficiency (g/m²/ºdays)						
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	At Harvest
Date of Sowing/ Sowing temperature (3)							
7thNov (24.5^{0}C)	0.10	0.14	0.18	0.33	0.45	0.52	0.47
17thNov (21.5^{0}C)	0.12	0.17	0.20	0.37	0.47	0.50	0.45
27thNov (18.7^{0}C)	0.14	0.18	0.22	0.37	0.45	0.48	0.43
Cultivars (3)							
Varuna	0.11	0.16	0.20	0.36	0.46	0.51	0.44
NDR-8501	0.12	0.17	0.21	0.37	0.49	0.52	0.48
NDR-4	0.11	0.15	0.17	0.34	0.41	0.47	0.45

Conclusion

Conclusively, maximum photo thermal Index (84.03) from sowing to maturity was obtained in NDR-8501 cultivar while minimum Photo thermal Index (80.51) was obtained in NDR-4 cultivar from sowing to maturity of Indian mustard. Maximum thermal use efficiency (0.48) requirement from sowing to maturity was obtained in NDR-8501 cultivar while minimum thermal use efficiency was obtained in Varuna (0.44) from sowing to maturity of Indian mustard.

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